

PATENT SPECIFICATION

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(54) IMPROVEMENTS IN THE DISSOLVING OF FINELY DIVIDED MATERIALS

(71) We, FREBAR HOLDING AG, a Swiss Company, of Im Oberleb 2, CH-6300 Zug, Switzerland, do hereby declare the invention, for which we pray that a patent 5 may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention is directed to a 10 process and apparatus for dissolving sugar and other soluble solids in water or other solvents.

Sugar is conventionally made available 15 in powder or crystalline form notwithstanding the advantages of liquid sugar to commercial users in the food manufacturing and processing industries. While such advantages associated with the use of liquid sugar are well known, transportation costs 20 involved in moving liquid sugar which are, of course, based on the total weight of the sugar and the water in the solution, mitigate against its more widespread use.

In the production of sugar solutions for 25 large scale commercial uses, such as in the baking, confectionery and similar food industries, the sugar is conventionally dissolved by adding sugar solids to agitated hot water. This technique for forming a 30 sugar solution has the disadvantage that when the sugar is first introduced into the hot water, the sugar solids tend to form agglomerated lumps or chunks which become glazed on their surface so that the 35 solution of the sugar crystals is inhibited. The reasons for this phenomenon are not particularly clear, but the following explanation is suggested. The hot water forms a concentrated solution when it first contacts 40 the outer crystals of the agglomerated lumps, and this concentrated solution penetrates inwardly in contact with the additional solid sugar. As it does so, the solid sugar within the mass becomes cooler, and 45 the sugar solution in contact therewith be-

comes saturated. The saturated solution becomes further cooled as it penetrates further into the agglomerated mass, and new crystals are formed in the interstices between the original sugar crystals which 50 cement the agglomerate together so that it cannot readily be permeated by the solvent. Such a mass of particles acts similarly to a chunk or mass of solid sugar and is difficult 55 to dissolve because of its limited surface area when compared to that of the original sugar crystals. The dissolving weight of such a mass of "cemented" particles is low, and large agitators and vessels are required. Similar phenomena occur when crystalline 60 solids other than sugar are dissolved in water and similar solvents so that dissolving such materials on a commercial scale may also be difficult and costly.

Various proposals have been made to 65 eliminate the disadvantages of conventional sugar dissolving systems, and have to some extent eliminated the agglomeration problem, but they have been unsatisfactory from the commercial standpoint. The previous 70 proposals have been based on the assumption that sugar and similar water soluble solids must be dissolved on a batch basis and no effective continuous process for the dissolution of such materials has yet 75 been developed. U.S. Patent Nos. 2,929,747 and 3,428,487 are examples of previous proposals for forming aqueous solutions of sugar and similar water soluble solids. While the procedure set forth in each of 80 these Patents may be effective to some extent in eliminating the agglomeration problem, they are unsatisfactory from the commercial standpoint because they are 85 batch processes.

Accordingly the invention provides a continuous process for forming a solution of a fine or powdered solid which comprises:

(a) introducing the solid and a solvent into a first dissolving vessel maintained 90

under such conditions of temperature and internal motion as to effect solution of a substantial portion of said solid;

(b) continuously withdrawing a portion 5 of the contents of the first dissolving vessel and introducing said portion into a second dissolving vessel maintained under such conditions of internal motion as to dissolve substantially all the solid not dissolved in 10 the first first dissolving vessel;

(c) continuously withdrawing a portion of 15 the contents of the second dissolving vessel and reintroducing said portion into the first dissolving vessel; and

(d) continuously withdrawing a solution 20 of the solid from the second dissolving vessel.

The flow of liquid which is desirable in 25 order to dissolve a substantial portion of the solid in the first dissolving vessel and/or substantially all of the remainder of the solid in the second dissolving vessel is, of course, rapid and turbulent. The net distribution of the contents of each of these vessels may be described as an axially symmetrical radial jet creating a random generally spiral motion. The preferred circulation of the contents in the second dissolving vessel may be obtained if the portion of the contents withdrawn from the first dissolving vessel is introduced into the second dissolving vessel through a centrally located tube having at an end within the second dissolving vessel a first nozzle, and first means for diverting the flow from said nozzle are positioned a short distance from said first nozzle. Similarly, a suitable circulation pattern in the first dissolving vessel may be provided if the portion of the contents withdrawn from the second dissolving vessel is reintroduced into the first dissolving vessel through a centrally located tube having at an end within the first dissolving vessel a second nozzle, and second means for diverting the flow from said second nozzle are positioned a short distance from said second nozzle. In a preferred design of nozzle, which establishes a very favourable circulation pattern when used in the first and/or second dissolving vessel, the means for diverting the flow from the first and/or from the second nozzle comprises a plate having a concave annular depression on the surface facing the nozzle.

55 The fine or powdered solid and the solvent are advantageously introduced into the first dissolving vessel in accordance with the measured concentration of the solid in the solution withdrawn from the second dissolving vessel. The contents of the second dissolving vessel are usually passed through a sieve prior to being withdrawn as the desired solution. For the production of concentrated sugar solutions (i.e. those having

60 a concentration of 60° Brix and above) the

contents of the first dissolving vessel are heated in response to a measurement of the temperature therein, conveniently by steam circulating in a jacket surrounding the first dissolving vessel. Usually from 50-90% by weight of the contents of the second dissolving vessel is reintroduced into the first dissolving vessel.

Most usually the fine or crystalline solid is sugar and the solvent is water. The aqueous solution of sugar withdrawn from the second dissolving vessel usually has a concentration of at least 60° Brix, and the process of the invention is especially suitable for the production of such concentrated 75 solutions.

In a further aspect the invention provides an apparatus for dissolving a fine or powdered solid in a solvent which comprises:

(a) a first dissolving vessel;

(b) means for introducing the solid into the first dissolving vessel;

(c) means for introducing a solvent for the solid into the first dissolving vessel;

(d) a first pipe for continuously withdrawing a portion of the contents of the first dissolving vessel and a pump associated with said pipe, one end of the pipe being in communication with the first dissolving vessel and the other end being in communication with the pump;

(e) a second dissolving vessel receiving the contents withdrawn from the first dissolving vessel through the pipe, a first conduit having one end connected to the pump and the other end located in the second dissolving vessel;

(f) a first nozzle attached to the end of the first conduit and located within the second dissolving vessel, and a first means for diverting the flow of contents from the first nozzle and spaced a short distance from the first nozzle;

(g) means for withdrawing a portion of the contents from the second dissolving vessel and recycling the withdrawn contents to the first dissolving vessel, said means including a second pipe having one end in communication with the second dissolving vessel and the other end in communication with a second conduit located in the first dissolving vessel;

(h) a second nozzle attached to the second conduit and a second means spaced a short distance therefrom for diverting the flow of recycled liquid from the second nozzle; and

(i) means for withdrawing the desired solution from the second dissolving vessel.

In the above apparatus the means for diverting the flow from the first and/or from the second nozzle advantageously comprises a plate having an annular concave depression on the surface facing the

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nozzle. The distance between the said nozzle and the plate is preferably from 0.5 to 3 times the diameter of the opening in the nozzle.

- 5 The second dissolving vessel will usually include at least one perforated plate to reduce the turbulence of the liquid in the upper portion thereof, and the means for withdrawing the desired solution will then 10 be in the said upper portion. A sieve is generally located in the path of the contents withdrawn from the second dissolving vessel as the desired solution. The apparatus will include means to measure the 15 temperature of the contents of the first dissolving vessel and means responsive to the temperature measurement to heat said first dissolving vessel. It preferably also includes means to measure the concentration of the 20 solid in the solution withdrawn from the second dissolving vessel and means to regulate the quantity of solvent introduced into the first dissolving vessel in response to the measurement of concentration.
- 25 A particularly preferred construction of the second dissolving vessel comprises a generally cylindrical mixing chamber, an inlet at the bottom of the mixing chamber, said inlet ending in a nozzle opening, means 30 spaced a short distance above the bottom of the mixing chamber in line with the flow of liquid from the nozzle opening to divert the flow of liquid from the nozzle, thereby causing an axially symmetrical radial jet 35 creating a random generally spiral motion, means for withdrawing the desired solution from the mixing chamber, and means to withdraw a portion of the contents of the mixing chamber for return to the first dissolving vessel, the withdrawal means having 40 associated therewith a sieve so that the desired solution withdrawn from said mixing chamber passes through the sieve.

The invention will now be further described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of the apparatus used to carry out the process of 50 the present invention;

Figure 2 is a cross-sectional view of a preferred second dissolving vessel; and

Figure 3 is a broken cross-sectional view taken along the line 4-4 of Figure 2 of the 55 sieve and related structure of the second dissolving unit.

As indicated previously, the present invention provides a process and apparatus for dissolving sugar and other soluble solids, 60 and is especially applicable to dissolving solids in aqueous media. The following discussion is directed primarily to the dissolving of sugar in water, but the invention can also be used to dissolve other soluble solids 65 which behave in a manner similar to sugar.

For example, mention can be made of such solid materials as alum, sodium hydroxide, and similar soluble solids or salts, all of which are embraced by the expression "fine or powdered solid". Similarly, while water 70 is the preferred solvent, any solvent suitable for the material to be dissolved can be employed and the expression "solvent" is means to embrace all such conventionally employed materials. However, the process 75 and apparatus described herein are particularly suitable for preparing highly concentrated aqueous sugar solutions, i.e. those of concentration of 60° Brix or more. Moreover, using the process and apparatus 80 described herein, it is possible to obtain the final solution at a desired concentration within a margin of $\pm 0.3^\circ$ Brix.

Referring to Figure 1, sugar is supplied 85 from any convenient source to a sugar hopper 10 located above a vibratory trough or moving endless belt 12 which conveys the sugar into a first dissolving vessel 14. Sugar hopper 10 is equipped with suitable means 90 of conventional design for measuring and controlling the level of the sugar crystals in the hopper.

The first dissolving vessel 14 has a water inlet 18, which may be at the side of the vessel as shown or may be at any other convenient point within the vessel. Sugar can 95 be dissolved in water at ambient temperatures up to a concentration of approximately 60° Brix. In this regard "Brix" refers to the concentration scale commonly used 100 in the food processing industry to refer to sugar solutions, a concentration of 60° Brix corresponding to 60 weight per cent sugar. When it is desired to form a more concentrated sugar solution or where crystalline 105 solids other than sugar are being dissolved in an aqueous or solvent system, it may be advantageous to heat the first dissolving vessel 14. A temperature indicator 20 of conventional design is located within vessel 110 14, and automatically controls the introduction of steam through line 22 by automatically opening and closing valve 24 in response to variations in the measured temperature. The steam introduced through line 22 heats the vessel 14 115 through a steam jacket 26 of conventional design, a steam trap 28 being provided to vent off condensate.

As indicated above, the formation of 120 sugar solutions of 60° Brix or less can be carried out at ambient temperatures. When heating is carried out to facilitate solution of further sugar, the first dissolving vessel 14 is generally heated to a temperature of 125 not more than 95°C.

A portion of the contents of the first dissolving vessel 14 is withdrawn through conduit 30 and pumped by pump 32 of conventional design into a second dissolv-

ing vessel 34. It is preferable to use a centrifugal pump of type conventional for use in the food processing industry.

The contents withdrawn from the first 5 dissolving vessel 14 are pumped into the second dissolving vessel 34 through a conduit 36, one end of which communicates with pump 32 and the other end of which is located within the second dissolving 10 vessel 34. The conduit 36 preferably has a nozzle opening 38 of the construction shown in detail in Figure 3, although a straight cut tube or a different design of nozzle known *per se* is also satisfactory.

15 As seen in Figure 1 a splash plate 40 is located a short distance from the nozzle opening 38 of tube 36 to divert the flow of liquid issuing therefrom. There is produced in the second dissolving unit 34 a net flow 20 which is an axially symmetrical radial jet creating a random generally spiral motion. The circulation is rapid and turbulent. The splash plate 40 has on the surface facing the nozzle an annular concave depression, 25 the shape of the said surface initiating a toroidal circulation of the contents in the second dissolving vessel 34.

As seen in Figure 1 and as more clearly seen by reference to Figure 2, the second 30 dissolving vessel 34 has perforated plates 42 which decrease the turbulence within its upper portion, the said turbulence desirably being kept to a minimum. While both Figures 1 and 2 illustrate the employment 35 of three such perforated plates, a lesser or greater number can be employed if desired or appropriate.

As further seen in Figure 2, splash plate 40 is movably connected to conduit 36. 40 Variation of the distance between the nozzle 38 and splash plate 40 may be brought about by sliding the mounting rod 44 in slot 46 formed within the conduit 36, and the plate may be fixed in any position by 45 set screw 48.

The distance between nozzle 38 and the splash plate 40 is from 0.5 to 3 times the diameter of the opening at the end of the nozzle. It has been found that when this 50 parameter is satisfied, maximum turbulence is created and the maximum mixing is obtained. There is imparted to the liquid in the vessel a generally spiral motion superimposed upon which there is a random 55 motion, and high rates of circulation can be attained. Furthermore, the curvature of the splash plate, which at its ends is of opposite sense to the direction of flow of the liquid emerging from the nozzle, has 60 a tendency to further accelerate the rotational spiral motion within the dissolving vessel.

In the upper portion of the second dissolving vessel 34, the sugar solution is 65 separated into a final product portion and

a portion for recycle to the first dissolving vessel 14. Preferably from 50% to 99% of the contents of the second dissolving vessel is recycled to the first dissolving vessel, the remainder being withdrawn as the final product. The recycled portion is passed out of vessel 34 by a centrally located tube 50, and contains a concentrated sugar solution and any undissolved sugar particles. All of the undissolved sugar particles in the second 75 dissolving vessel 34 are recycled into the first dissolving vessel 14 and do not pass into the product.

The flow of recycle portion in tube 50 is controlled by a valve 52. At the end of 80 tube 50 within the first dissolving vessel 14 there is provided a second conduit 54 having a nozzle opening 56 at its end, a splash plate 58 being spaced a short distance from said nozzle. The arrangement of splash 85 plate 58, nozzle 56 and conduit 54 is substantially identical with the arrangement within the second dissolving vessel 34. Again, however, the use of such a nozzle and splash plate arrangement is a preferred feature of the invention, and can if desired be replaced by other conventional means such as straight cut tubes. As an alternative to the use of the splash plate 58 in the first dissolving vessel 14, the 95 nozzle can be sufficiently close to the bottom of the vessel for the bottom of the vessel to divert flow of the recirculated liquid and produce the desired net flow of contents.

100 The flow of the contents of vessel 14 is indicated in Figure 1 by arrows. The use of the splash plate, however, is preferred because its shape readily gives rise to the desired circulation, and the rapid turbulent 105 motion which is created allows for a more efficient mixing of the sugar crystals and water than possible with conventional mechanical or turbine mixers and assists rapid solution of the sugar in the water in a 110 manner not heretofore possible with conventional apparatus. In the first dissolving vessel 14 a substantial portion of the sugar crystals are rapidly dissolved, and there passes to the second dissolving vessel 34 a 115 concentrated sugar solution containing a substantially reduced amount of sugar crystals.

120 Referring to the second dissolving vessel as shown in Figure 2, the portion of the contents of the second dissolving vessel 34 which is not recycled to the first dissolving vessel 14 passes out as the final product, i.e. a concentrated sugar solution. The final product is withdrawn from 125 second dissolving vessel 34 through line 59 after passing through a perforated plate 60 having on its up-stream side a sieve 62. The arrangement of the perforated plate 60 and sieve 62 is shown in greater detail 130

in Figure 3.

As seen in Figure 2, the perforated plate 60 is in the form of a cone with a sieve 62 covering its up-stream side. The mesh size 5 of the sieve is selected to prevent an appreciable amount of undissolved sugar crystals from passing out of the second dissolving vessel 34. The mesh size of sieve 62 can be smaller than the sugar crystals, 10 but it has surprisingly been found that even where the mesh size of sieve 62 is larger than the remaining sugar crystals, substantially no sugar crystals pass through sieve 62, perforated plate 60, and out through line 59. While the reason for this phenomenon is not quite clear, it appears that sugar crystals can dissolve on sieve 62. The mesh size of sieve 62, i.e. the width between wire and wire, is preferably about 0.25 mm, 15 whereas the sugar crystals in the second dissolving vessel 34 generally has sizes between 0.1 and 1.5 mm. Notwithstanding the fact that the mesh size of sieve 62 can be larger than the crystal size of the sugar, the 20 sugar crystals do not pass through sieve 62 and perforated plate 60, but rather substantially all of the undissolved crystals are recycled into the first dissolving vessel 14 through line 50. As seen in Figure 1, product line 59 and recycle line 50 contain 25 90° bends and control valves or orificed plates (blockages) can be inserted within the lines so as to create the necessary pressure drop to effect the desired flow of 30 contents through recycle line 50 and through product line 59. By proper selection the 35 desired flow of the concentrated sugar solution out of the second dissolving vessel 34 through line 59 may be maintained 40 together with a constant recycle of the sugar syrup and undissolved crystals through line 50 back into the first dissolving vessel 14. The second dissolving vessel 34 need not be 45 equipped with a steam jacket or other means to heat the vessel. Owing to its small size, heating is not required to effect further solution of the sugar crystals undissolved in the first dissolving vessel 14.

The product passing out of the second 50 dissolving vessel 34 through line 59 passes to a suitable means for measuring the density or concentration of the sugar in the solution, for example a conventional refractometer. To maintain the desired sugar 55 concentration in the final solution, the measurement of the density or concentration automatically controls valve 64 located in the water inlet line 18. Accordingly, through this arrangement, the amount of water 60 introduced into the first dissolving vessel 14 is automatically controlled in response to the measurement of the density of the final sugar solution or concentration of sugar therein. Water inlet line 18 is equipped 65 with a bypass 66 and an associated valve

68, which bypass and valve allow the water to be introduced notwithstanding the density or concentration measurement. The bypass line 66 and valve 68 can be used when the process is started up. Downstream 70 of the density or concentration control means 70 is a bypass line 72 which, through valve 74, leads back to the recirculating line 50 between the second dissolving vessel 34 and the first dissolving vessel 14. This 75 bypass line 72 can be used when starting up the process. There is also provided an automatic safety shut-off valve 76 located downstream of the density or concentration measuring means 70. During the start-up 80 operation, valve 76 is closed. Water is fed into the first dissolving vessel 14 through line 18, and subsequently passes through pipe 13, pump 32 and conduit 36 into the second dissolving vessel 34. When the 85 second dissolving vessel has been filled, water passes through line 59, concentration control unit 70, bypass line 72, recycle line 50 and reactor tube 54 and then returns to the first dissolving vessel. Sugar is continuously added to the system, and when both the recirculated liquid and the product in line 59 have achieved the desired concentration, the refractometer 70 automatically opens the valve 76 so that the product 90 may be withdrawn. After the start-up operation is complete, the refractometer 70 controls the amount of water fed into the unit by measuring the concentration of the sugar in the final product, thereby allowing 95 100 addition of food flavouring materials.

WHAT WE CLAIM IS:

1. A continuous process for forming a solution of a fine or powdered solid which comprises:
 (a) introducing the solid and a solvent into a first dissolving vessel maintained under such conditions of temperature and internal motion as to dissolve therein a substantial portion of said solid; 110
 (b) continuously withdrawing a portion of the contents of the first dissolving vessel and introducing said portion into a second dissolving vessel maintained under such conditions of internal motion as to dissolve substantially all the solid not dissolved in the first dissolving vessel; 115
 (c) continuously withdrawing a portion of the contents of the second dissolving vessel and reintroducing said portion into the first dissolving vessel; and 120
 (d) continuously withdrawing a solution of the solid from the second dissolving vessel.
2. A process according to claim 1 130

- wherein the solid and the solvent are introduced into the first dissolving vessel in accordance with the measured concentration of the solid in the solution withdrawn from the second dissolving vessel.
3. A process according to claim 1 or 2 wherein the contents of the second dissolving vessel are passed through a sieve prior to being withdrawn as the desired solution.
- 10 4. A process according to any preceding claim wherein the contents of the first dissolving vessel are heated in response to a measurement of the temperature therein.
5. A process according to claim 4 15 wherein the heating is conducted by steam circulating in a jacket surrounding the first dissolving vessel.
6. A process according to any preceding claim wherein 50 - 99% by weight of the 20 contents of the second dissolving vessel is reintroduced into the first dissolving vessel.
7. A process according to any preceding claim wherein the flow of liquid within the first dissolving vessel and/or in the second 25 dissolving vessel is an axially symmetrical radial jet creating a random generally spiral motion.
8. A process according to any preceding claim wherein the flow of liquid within the first dissolving vessel and/or within the second dissolving vessel is at least partly turbulent.
9. A process according to claim 7 or 8 30 wherein the portion of the contents withdrawn from the first dissolving vessel is introduced into the second dissolving vessel through a centrally located tube having at an end within the second dissolving vessel a first nozzle, and first means for diverting the flow from said nozzle are positioned a short distance from said first nozzle.
10. A process according to claim 7, 8 or 9 wherein the portion of the contents withdrawn from the second dissolving vessel 35 is reintroduced into the first dissolving vessel through a centrally located tube having at an end within the first dissolving vessel a second nozzle, and a second means for diverting the flow from said second nozzle are positioned a distance from said second nozzle.
11. A process according to any of claims 7 - 10 wherein the means for diverting the flow from the first and/or from the second nozzle comprises a plate having a concave annular depression on the surface facing the nozzle.
12. A process according to any preceding claim wherein the fine solid is sugar 40 and the solvent is water.
13. A process according to claim 12 wherein the aqueous solution of sugar withdrawn from the second dissolving vessel has a concentration of at least 60° Brix.
- 65 14. A process according to claim 1 sub-
- stantially as hereinbefore described with reference to the accompanying drawings.
15. An apparatus for dissolving a fine or powdered solid in a solvent which comprises:
- (a) a first dissolving vessel;
 - (b) means for introducing the solid into the first dissolving vessel;
 - (c) means for introducing a solvent for the solid into the first dissolving vessel;
 - (d) a first pipe for continuously withdrawing a portion of the contents of the first dissolving vessel and a pump associated with said pipe, one end of the pipe being in communication with the first dissolving vessel and the other end being in communication with the pump;
 - (e) a second dissolving vessel receiving the contents withdrawn from the first dissolving vessel through the pipe, and a first conduit having one end connected to the pump and the other end located in the second dissolving vessel;
 - (f) a first nozzle attached to said end of the first conduit and located within the second dissolving vessel, and a first means for diverting the flow of contents from the first nozzle spaced a short distance from the first nozzle;
 - (g) means for withdrawing a portion of the contents from the second dissolving vessel and recycling the withdrawn contents to the first dissolving vessel, said means including a second pipe having one end in communication with the second dissolving vessel and the other end in communication with a second conduit located in the first dissolving vessel;
 - (h) a second nozzle attached to the second conduit and a second means spaced a distance therefrom for diverting the flow of recycled liquid from the second nozzle; and
 - (i) means for withdrawing the desired solution from the second dissolving vessel.
16. An apparatus according to claim 15 110 wherein the second dissolving vessel includes at least one perforated plate to reduce the turbulence of the liquid in the upper portion thereof.
17. An apparatus according to claim 15 115 or 16 wherein the second dissolving vessel further includes a sieve located in the path of the means for withdrawing from said second dissolving vessel the desired solution.
18. An apparatus according to any of 120 claims 15 - 17 including means to measure the temperature of the contents of the first dissolving vessel and means responsive to the temperature measurement to heat the first dissolving vessel.
19. An apparatus according to any of 125 claims 15 - 18 further including means to measure the concentration of the solid in the solution withdrawn from the second dissolving vessel and means to regulate the

quantity of solvent introduced into the first dissolving vessel in response to the measurement of concentration.

20. An apparatus according to any of claims 15 - 19 wherein the means for diverting the flow of contents from the first nozzle and/or from the second nozzle comprises a plate having a concave annular depression on the surface facing the nozzle, said depression being symmetrically disposed in relation to said nozzle.

21. An apparatus according to claim 15 wherein the second dissolving vessel comprises

15 a generally cylindrical mixing chamber, an inlet at the bottom of the mixing chamber, said inlet bending in a nozzle, means spaced a short distance above the bottom of the mixing chamber in line with 20 the flow of liquid from the nozzle opening to divert the flow of liquid from the nozzle thereby causing an axially symmetrical radial jet creating a random generally spiral

motion, means for withdrawing the desired solution from said mixing chamber, and 25 means to withdraw a portion of the contents of the mixing chamber for return to the first dissolving vessel, said withdrawal means having associated therewith a sieve positioned so that the desired solution with- 30 drawn passes through said sieve.

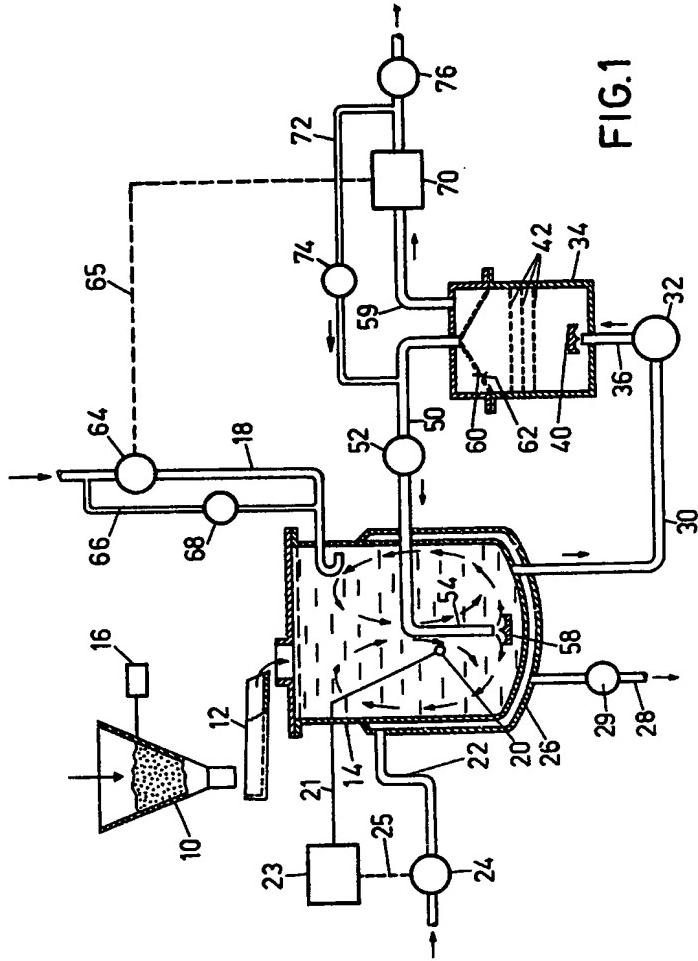
22. An apparatus according to claim 20 wherein the distance between the first or second nozzle's opening and the respective plate is 0.5 - 3 times the diameter of the 35 opening in the respective nozzle.

23. An apparatus according to claim 15 substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings. 40

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